RIVISTA INTERNAZIONALE DI FILOSOFIA E PSICOLOGIA
DOI: 10.4453/rifp.2013.0012
ISSN 2039-4667; E-ISSN 2239-2629
Vol. 4 (2013), n. 2, pp. 134-142

Studi

The "Other" Localization: XIX Century French Neurophysiological Models for the Seat of the Musical Faculty in the Brain

Mattia Della Rocca

Ricevuto il 6 ottobre 2012, accettato il 24 aprile 2013

Abstract At the beginning of the second half of the XIX century, Paul Broca's discoveries on the localization of the seat of the articulated language faculty laid the foundations for modern neuropsychology, confirming the localizationistic hypothesis to the detriment of previous theories of mind-body interaction. This epoch also recorded the first scientific observations on the relationships between music and the nervous system: in the present essay, we trace the genesis and the history of the models debated by the French scientific community of the XIX century, analyzing them through the works of the most famous authors of that period, and reflecting on their implications for subsequent developments in the psychology and neuroscience of music.
KEYWORDS: Music; Faculty; Brain; Localization; History of Neuropsychology.

Riassunto *L'"altra" localizzazione: modelli di localizzazione cerebrali delle facoltà musicali nella neurofisiologia francese del XIX secolo* – All'inizio della seconda metà del 1800, le scoperte di Paul Broca sulla localizzazione della facoltà del linguaggio articolato gettarono le basi per la nascita della moderna neuropsicologia, confermando l'ipotesi localizzazionistica delle funzioni mentali a discapito delle precedenti teorie sull'interazione tra mente e corpo. A questo periodo risalgono le prime osservazioni scientifiche sul rapporto tra musica e sistema nervoso: nel presente contributo, tracceremo la genesi e le vicende dei modelli discussi nella comunità scientifica francese del XIX secolo, analizzandoli a partire dai testi dei più importanti autori del periodo e riflettendo sulle loro implicazioni per i successivi sviluppi della psicologia e delle neuroscienze della musica.
PAROLE CHIAVE: Musica; Facoltà; Cervello; Localizzazione; Storia della neuropsicologia.

THE ROLE OF BROCA'S AREA in music, together with its involvement in motor and verbal production, is nowadays well established. At the time of the discovery of its connection with articulated language, however, this no correlation seemed impossible, or, at the very least, questionable.

The new research paradigm, however, already included the right tools for this further elaboration, since the neuropsychological approach not only linked cognitive functions to brain areas but also played a decisive role in the exploration of the rich organization of complex behaviors and mental processes.

Since these early times, the cognitive and behavioral neurosciences have contributed to

M. Della Rocca - Dipartimento di Studi Umanistici - Università di Roma "Tor Vergata" (✉)
E-mail: mattia.dellarocca@gmail.com

the definition of the functions they study. Language – as Broca himself clearly showed – was obviously a perfect candidate to fit the role of the paradigmatic object of investigation. But what about other aspects of behavior and cognition unique to humans? And, more specifically, what about music?

In XIX century France, when a dispute between different theories on the role of the brain in mental activity was in full swing, music also established its position as a psychological (and, of course, neuropsychological) object of study. Furthermore, the scientific literature of the time provides a direct record of the importance of this topic in the debate on the localization of mental functions in the brain.

Far from being a simple ancillary *addenda* to the exposition of neurophysiological models, observations on the effects of musical experience on neural structures defined the foci of subsequent debates on this topic for time to come, building the foundations for many contemporary views on the subject. [1]

Early issues related to localization of musical ability

The very first attempt to establish a correlation between a region of the brain and the ability for music can be traced back to Costanzo Varolio (1543-1575), who wrote in his *Anatomiae* (published posthumously in 1591) that the cerebellum was the seat of hearing, along with the senses of touch and taste, probably because of the close proximity between this structure and the nerves associated with these two modalities.

Varolio's dissection techniques and discoveries on the anatomy of cranial nerves were welcomed by the scientific community of the epoch: however, his reflections on music were not pursued, and following the work of this Italian anatomist there were no further attempts to establish a connection between music and the brain in the XVI century.

In the middle of the XVII century, a short essay entitled *Compendium Musicae* by René Descartes (1596-1650), originally written in 1618, was posthumously published. In the *Praenotanda* to the volume, which mainly focused on the definition of contemporary music theory, a young Descartes provided a musical foretaste of what would become his mechanistic and dualist views on living beings. In fact, he wrote that:

> every sense is capable of feeling pleasure. For this pleasure to occur, a certain proportion between the object and the sense is needed. Consequently, the bellow of lightning and thunder does not seem appropriate to music, because it will in fact hurt the ears, as the brightening of the sun hurts the eyes. The object must not fall under the sense in a difficult way, or in a confusing manner.[2]

Although this excerpt on its own might suggest a full identification of the musical faculty with the anatomical ear, in the second chapter of the volume, Descartes traced a sharper distinction between the pure and simple perception of music as a physical phenomenon and the ability to perceive, conceive, and feel pleasure in it. Rhythm and harmony consist in good proportions of natural sounds and anybody can perceive this, or even be influenced by exposure to it: but it takes a soul to make rhythm and harmony into music, because only a human mind can think of it in this terms.

«Even animals can dance, if trained, because only natural instinct is required for this»,[3] Descartes wrote, and he continued to describe how the real *locus* of musical experience is in the "*cognitione motuum animi*", the movements of the soul, which do not belong to either the physical or physiological dimensions, «for music was created for the pleasure of our Souls».[4]

This assertion, already containing the mechanistic body paradigm he would fully express in the pages of his *De Homine* in 1633, implies that the human propensity for music is part of our *modi cogitandi*, and the anatomical structures necessary for it are just a tool, no matter how perfect or sophisticated they may be: in other words, this is the formulation of the musical version of the mind-body problem.

Descartes' thoughts on music contributed

to a revival of the so called "*teoria degli affetti*", the "theory of the affects" which had dominated musical aesthetics throughout the XVIII century; and, of course, they promoted a quest for a better knowledge of acoustical laws and an improved understanding of the anatomical structure of the auditory system. However, by according music a place in the activity of the *res cogitans*, they entailed a setback for the investigation of music in the brain: a (metaphysical) mind, together with a good pair of ears (and a pineal gland, of course), was all men needed to enjoy the pleasure of music.

Descartes' ideas on the brain, however, were soon refuted by some scholars of his time: and the musical issue emerged again in the work of the English anatomist Thomas Willis (1621-1675). Willis was not convinced by the account of brain functions presented by Descartes, favoring a different idea of the brain, with anatomical and functional differentiation.

Revisiting Varolio's observations on the cerebellum, in his *Cerebri anatome* of 1664, the English physician asserted that the cerebellum was responsible for the musical ear of man. Willis believed that "animal spirits" moved by the impression of sounds around us leave a trace of their passage in the cerebellum, because of the evident connections between this structure and the auditory nerves. Music was not independent from the faculty of reasoning, proper to the brain, but was in any case located in an area that he considered to be the a gateway and filter for auditory and musical perception.

> Because the act of listening depends on the cerebellum, this organ is predisposed to be crossed through by and to receive these animal spirits; and it is plausible that they also convey ideas and impress traces of memories, so that when a vocal sound has to be emitted, the sound previously listened to is emulated, and the vocal act is accomplished. From this results the fact that some men can easily learn melodies.[5]

Willis also thought that the anatomical softness of the cerebellum was both a clue supporting his hypothesis and a marker for more or less pronounced musical ability. In Willis' work of 1664 we can find the first use of the terms "musical faculty" and "musical ear": however, no other attempt to study the relationship between music and the brain was pursued until a new approach to the mind in the brain was developed, at the end of XVIII century, by the German philosopher and physiologist Franz Joseph Gall.

Phrenology and music

When Franz Joseph Gall (1758-1828) presented, together with his friend and colleague Johan Gaspar Spurzheim (1776-1832), his "organological" or "phrenological" theory to a French audience in 1810, with the publication of *Anatomie et physiologie du système nerveux en general, et du cerveau en paiticulier, avec des observations sur la possibilité de reconnâitre plusieurs dispositions intellectuelles et morales de l'homme et des animaux par la configuration de leurs têtes*, many walls came tumbling down.

Phrenology was a wide anatomo-functional system, based on the concept that the brain is the organ of the mind, and that certain brain areas are dedicated to specific functions or modules. Phrenologists believed that the mind was organized into different mental faculties, each of them hosted in a different area of the brain. From the evaluation of these areas through the palpation of the cranial bone, Phrenology pretended to discover propensities, lacks and even the very destiny of an individual, as well as his morality or – to present a good example of phrenological science – his potential to be a good parent.

Even if it was soon branded as pseudoscience by the scientific community (although its fame as a "popular science" grew, above all in the United States of America, all through the XIX century), the discipline founded by Gall renewed and focused the attention of physiologists of the time on the possibility of localizing mental functions in the brain, thereby directly influencing the next wave of neurological discoveries.

Of course, music could not be excluded from the omni-inclusive phrenological architecture. Cranioscopically speaking, Gall supposed that the faculty of music (number 17 of 27 in his original formulation of phrenological theory) was located in the forehead of men, and that it could assume two different appearances:

> Or the exterior angle of the forehead, immediately above the external angle of the eye, expands toward the temple; and in this case the lateral parts of the forehead exceed the eye angle, then all the frontal region above it until the mid-height of the forehead , is rounded. Or a pyramidal prominence appears, its base set above the eyes and its peak extending to the anterior and external border of the forehead, up until its midpoint.[6]

For the sake of the fashion of the time, Gall added support to his theories on the location of musical faculty with reports of observations of crania from Haydn, Rousseau, Beethoven, Gluck and both the Mozarts.

It is the account of this discovery, carefully narrated by Gall himself, which highlights an interesting point in the history of the psychology of music. Why should we need, Gall asked his readers, a specific organ for music in the brain? And what should its characteristics be?

The German physician starts the paragraph dedicated to musical talent with a detailed account of his efforts to provide these answers. In the first instance, he rejects the mechanistic "ear hypothesis". Gall uses comparative data in a negative way, reporting on several non-human animals which have a bigger (often meant as "a better") auditory system than humans yet do not make music, in order to exclude any correlation between features characterizing the ears and an ability for music.

The same treatment is reserved, a few paragraphs later, for the hypothesis of a correlation between musical inclination and the anatomical structure of human phonation, since in Gall's opinion, «the throat is just a tool, as is the hand for the painter and the sculptor».[7] Discussing the localization of the music faculty in the brain, Gall further discards Willis' cerebellar hypothesis, rejecting it in a few lines, because «[Willis] could not demonstrate his opinion with facts nor reasoning».[8] Consequently, the father of Phrenology, had nothing left to do except to admit the existence of a specific organ devoted to the faculty of music in the brain, located exactly above the corner of the eye.

But what characterizes this organ, what are its functions, the object of its actions? Since Gall observed that many people could easily retain melodies even in the absence of a strong memory for words or faces, and phrenological theory postulated that every organ had its own specific dedicated memory system, he deduced that the organ of musical talent was the organ responsible for the perception, memory and imagination of melodies. Melodies are, by definition, a related set of two or more tones: so Gall deduced that the faculty of music was a sense for tone relationships. With this formulation, Gall was the first author to address the problem of the definition of what a hypothetical "musical faculty" might be, and he choose to emphasize melodic aspects of music rather than rhythmical ones.

Thus, in an interesting sense, the development of the phrenological approach to musical abilities foreshadowed their modern modular conceptualization by appealing to inter-modular variability in explaining inter-individual differences in musical talent. Reading the words of Giovanni Antonio Lorenzo Fossati (1786-1874), a fervent supporter of Gall's theories and president of the *Societé Phrénologique* of Paris, we know that:

> after the sounds-relationship organ, which we have discussed, the organ of time must be the first to sustain the musician; for meter and rhythm are necessary to music [...] The subtlety of the organ of touch contributes the same, for its part, to the perfection of musician talent [...] Musical genius, supported or helped by different faculties, has different manifestations, because of the difference between these faculties.[9]

To get an idea of how innovative this approach was for its first XIX century audience, we can turn to the words of François Joseph Victor Broussais (1772-1838), who in his last years spent many of his public lessons advocating Phrenology. In 1836 he clearly wrote in his *Cours de Phrénologie*:

> Another faculty, placed by the phrenologists amongst the intellectual ones, and of which philosophers cannot say a word, is that of the sense of tone, of melody. It must be confessed, in fact, that philosophers have been quite silent and sterile on this point, not knowing what to say. What can they do with it? Should it be a quality of their "Being", material or immaterial,, imprisoned in the brain? Well, please, tell us what is this faculty of "being". Phrenology points to an organ for this [musical] faculty. And you leave it in the *flesh*, without showing its relationship to the *mind*.[10]

With respect to music (as for the other "intellectual" faculties), phrenologists tried to relate a cerebral area to a specific function, defining at the same time what music should be as a psychological object of study. Because of this, however, phrenology met with some severe objections – most of them well deserved – from physicians and scientists inspired by the Cartesian philosophy of dualist interactionism.

Reactions to phrenology

When we talk of the struggle against Phrenology in France, we are, of course, talking about the fierce opposition to Gall's discipline by Marie Jean Pierre Flourens (1794-1867), the famous French physician responsible for extensive experimental research on the human nervous system. His works *Examen de la phrénologie,* published in 1842 and *De la phrénologie et des études vraies sur le cerveau* in 1862 contain several arguments against Gall's philosophy as well as his physiology.

As is well known, Flourens opposition to this model of mind-brain interaction was based on the results of his experimental research: according to his interpretation of nervous system function, it was possible to attribute the control of vegetative and involuntary action to the brainstem, the control of motor actions to the cerebellum and that of general reasoning to the two hemispheres of the prosencephalon, where the principle of equipotentiality (being influenced in this assumption by Albrecht von Haller's "common action"[11]) made the forebrain the only possible seat of a unitary, single intelligence.

His remarks on the unity of mind are clearly a direct heritage from Cartesian philosophy: mind is, according to Flourens, the soul, the unique and coherent *cogito* depicted by René Descartes – to whom Flourens' 1842 book is dedicated - for his works of "*bonne philosophie*".

The logic and the coherency of Flourens' arguments against Phrenology exerteda great influence on the XIX century French scientific community, leading to a massive rejection of approaches based on the separation of mental faculties, and their hypothetical localization through the measurement of crania. Even if Flourens himself never went deeply into the specific debate on the hypothetical "musical faculty" of Gall's phrenology, his ideas influenced (and were influenced by) other authors, who in their works also addressed the issue of the relationship between musical abilities and the brain.

The most significant example comes from a simple comparison between the lines we cited a few paragraphs back from Descartes' *Compendium* and the words of François Magendie (1783-1855) in his *Précis elementaire de physiologie*, dated 1836, a text filled with strong claims that phrenology was nothing but a pseudoscience. The famous French physician, after a long description of both the physical properties of sound and the anatomical structure of the outer and inner ear, firmly (and honestly) writes that:

> it is impossible to explain the action of the acoustic nerves, nor that of the brain, in audition, but there are some observations which can be made about them. Sounds, in order to be perceived, must be within a cer-

> tain range of intensity. A sound that is too loud hurts us, while a too feeble one cannot produce a sensation [...] music, organizes and combines sounds. For ears organized to perceive it, music is without doubt the first of all arts, since no other can produce sensations more keen and delicious.[12]

Even without knowing how much Magendie and Flourens admired each other (the latter wrote a touching funeral oration for the former in 1858[13]), the echo of their common Cartesian background can be clearly heard throughout this excerpt.

In 1842, Frédéric Dubois d'Amiens (1799-1873) wrote that, in every single musician he had known, there had been no trace of the "roundness" Gall had postulated to mark the seat of the musical faculty.[14] Other academicians also tried, in those years, to undermine phrenological theories of musical ability, carefully comparing the data Gall had provided in his works with other observations on animal physiology. Louis François Lelut (1804-1877) openly doubted Gall's comparative studies of human and birds, in his 1843 *Rejet de l'organologie phrénologique*:

> Does he [Gall] say that the organ of music gives the orbital arch of the nightingale cranium a roundness no sparrow or goldfinch could ever have? I have investigated this comparison, and found that, more than any other bird, the goldfinch should be an even better singer than the Philomele.[15]

These observations, particularly those concerning the lack of confirmation for Gall's comparative studies, had a major impact on the anatomical progress of the time. This renewed focus on the anatomy of the inner ear lead, in 1851, to the discovery of the fine stereociliar organization of the mammal cochlea by the Italian anatomist Alfonso Giacomo Gaspare Corti (1822-1876).

This discovery turn lead to intensified studies on auditory perception, like those which in 1863 came to constitute the core for the famous *Die Lehre von den Tonempfindungen* by Hermann Helmloltz (1821-1894).[16] Such physiological advances probably provided some relief for the anti-phrenologist front, apparently constituting the last word on the dispute on the localization of musical abilities, since physiological structures directly responsible for the discrimination of pitches had finally been found and described.

In 1861, however, Broca's reports on the direct correlation between the loss of speech and the partial destruction of the anterior left lobe of the brain again shook the tenets of XIX century physiology. If language could be located in a specific area, might music have the same fate?

Consequences of Broca's localization of articulated language

Even if Paul Broca never claimed Gall's work as a direct source of inspiration for his research, it is clear how much influence phrenology had exerted on the scientific community of the XIX century. The localization of the seat of articulated language in 1861 by the French neurologist laid the foundations for a new science, but raised many objections at the time.

The focus of the medical community quickly shifted to reporting aphasia cases, trying to deny, correct or improve the findings of Broca. Music soon gained a special role also in this debate: all through the second half of the century, new series of observations on the connection between music and brain injuries were published, in the shape of new (or "dug out" from the past literature) clinical reports where musical abilities appeared to be impaired while language was not, or *vice versa*.

In 1865, the French *Académie de Médicine* heard Jean-Baptiste Bouillaud (1796-1881) give an account of "Monsieur P.", a patient of Hilaire Lerpinière, who was unable to speak because of a severe aphasia, but apparently preserved the ability to compose, play and hum music:

> [Monsieur P.], whose main occupation was music when he was wealthy, was advised by his wife to compose and write down some

> notes. He took a music sheet and, with no hesitation, wrote a few musical lines, which his wife played on the piano *astonished* by its precision and lack of errors. Then he started to modulate his voice to the song he had written, and he accompanied with skillfulness and harmony the sounds of his voice on the piano, without even a minor mistake in the articulation of the appropriate sounds.[17]

Jules Philippe Joseph Falret (1824-1902), writing in 1866 the entry *Aphasie, Aphémie et Alalie* for the *Dictionnaire encyclopédique des sciences médicales* edited by Amédée Dechambre, dedicates an interesting paragraph to musical abilities in aphasic subjects.

> Singing, a sort of intermediary between scream and articulated language, can persist in aphasics who have almost completely lost the use of speech: but it is necessary to distinguish between two distinctive categories in these cases of singing conservation. Some individuals, in fact, cannot articulate the words of an air and only preserve the ability to hum them with the addition of the few words or monosyllables they still retain; others can actually pronounce, while singing, words they cannot articulate in speech.[18]

Falret goes further and reports another clinical observation, this time reported by Luis Jules Béhier (1813-1876), dated 1836 which concentrated on a syphilitic male who developed motor aphasia but was still able to sing *La Marseillaise* through the intonation of the single syllable "*tan*" – curiously, the same syllable pronounced by Broca's most famous patient, "Monsieur Leborgne" or, as he became famous, "Tan".

These reports make it clear how the lexicon and models for understanding music and the brain changed after Broca's findings on language. Initially accorded a single faculty depending primarily on perception, musical abilities had differentiated into different functions, in a manner paralleling the development of language theory language throughout the XIX century. Musical ability could be impaired, after a cerebral lesions, in many peculiar ways: the ability of singing could be damaged as well as the ability for musical perception, just like the faculty of writing or reading musical notation.

Outside France, John Hughling Jackson (1835-1911) published in 1866[19] and in 1871[20] several accounts of children unable to speak any words but perfectly able to sing, a fact he attributed to the substantial differences between what he called "emotional" and "intellectual" language. This ultimately lead, in France, to the revival of Willis' opinions on the role played by the cerebellum (a hypothesis which, in fact, French physiologists had never really given up, as demonstrated by the *Traité de Physiologie Comparée de l'Homme et des Animaux* by Antoine Luis Dugès, published in 1838).

In 1891, Frédéric Courmont could also still write a passionate defense of the cerebellum as the seat of musical abilities (according to him it should be accorded the general status of the "emotional brain"), providing evidence and arguments from the anatomy of the cranial nerves to support his case,[21] as did a clinical observation by Paul Joseph Barthez (1734-1806), where an account is given of a girl affected by seizures after severe cerebellar damage who could no longer speak without stuttering but was still able to sing (apparently overcoming her crisis).[22]

The revised cerebellar hypothesis was, in any case, just an echo of the past. Since Bouillaud's first observations in 1865, every reported case of musical and non-musical aphasia, had established a different model of musical function, a model inspired by the model applied to language after Carl Wernicke's work of 1874.[23]

In 1888, it was the German physician August Knoblauch who coined the term "amusia" referring to musical perception and production disorders.[24] With the publication of the essay *L'Amusie* in 1893 by Paul Oscar Blocq (1860-1896), a neuropathologist at the Salpétrière hospital, the French medical community showed how perfectly it had assimilated the topic of musical disorders, categorizing them as peculiar forms of aphasia. Blocq described how under the umbrella-term "*amusia*", different

dysfunctions must be distinguished: there were receptive or sensorial *amusias* (including "real" or auditory *amusia* and musical *alexia*) and expressive or motor *amusias* ("real" musical motor *amusia*, musical *amimia* or an impairment for playing instruments as well as musical *agraphia*).[25]

At the end of the century, normal and abnormal music psychology strictly resembled the psychology of language, the former borrowing from the latter models, hypotheses and styles of clinical observation.

Learning from the past

As we have seen, music as a topic in psychology and the neurosciences, underwent a complex process of definition in the XIX century. After early attempts at localization during the XVI and XVII centuries, with the advent of phrenology music was officially declared to be a "faculty" involving both the brain and the mind.

This raised doubts, questions and objections to the original locationationist claims, while at the same time stirring up the localizationistic hypotheses of the time. This led to the contraposition of a Cartesian model, where the mere sense of hearing and the ability of the *cogitans* mind were sufficient to justify musical experiences, and a phrenological model, which proposed a specific seat in the brain for the sense of tone relationship. It is interesting to note how these two approaches foreshadow a major division of opinion in contemporary musical psychology, that is, the debate as to whether music is a secondary (and even casual) byproduct of human general-intelligence, as claimed by Pinker,[26] or whether it constitutes a distinctive feature of our species, based on brain areas positively selected through evolution, as claimed by many authors in the neuroscience of music. [27]

Both of these models were largely abandoned soon after Broca's discovery of the seat of articulated speech, which made way for a different paradigm, similar to that hypothesized for language and differentiated on the base of the range of musical dysfunctions observed in clinical cases.

This model too – later neglected in order to favor a more marked separation between "emotional" and "intellectual" language, as a consequence of the hemispheric differentiation trend of the 1940s – predates the present arguments concerning modularistic musical functions and the neural overlap between language and music areas, as respectively explicated by Peretz[28] and Patel.[29]

In other words, it looks as if the XIX century physiologists' observations sowed the seeds for the modern psychology of music: and this suggests, to historical, theoretical and philosophical psychology, that further studies should compare these models, in order to gain further insight into the formulation of valuable research paradigms for the future.

Notes

[1] All the citations in the present essay were translated from French by the Author. A selection of the original texts cited can be found at the address http://amindbodyproblem.org/brocamusicsources/

[2] R. DESCARTES, *Compendium Musicae* (1618), in: R. DESCARTES, *Oeuvres de Descartes*, vol. X, edited by C. ADAM, P. TANNERY, L. Cerf, Paris 1908, p. 58.

[3] *Ivi*, p. 36.

[4] *Ibidem*.

[5] T. WILLIS, *Cerebri Anatome*, Typis J. Flesher, Impensis J. Martyn & J. Allestry, London 1664 (p. 215).

[6] F.J. GALL, *Anatomie et physiologie du système nerveux en général, et du cerveau en particulier avec des observations sur la possibilité de reconnâitre plusieurs dispositions intellectuelles et morales de l'homme et des animaux, par la configuration des leurs têtes, Volume IV, Physiologie du cerveau en particulier*, Chez N. Maze, Paris 1819, p. 118.

[7] *Ivi*, p. 120.

[8] *Ivi*, p. 121.

[9] G.L. FOSSATI, *Questions philosophiques, sociales et politiques traitées d'après les principes de la physiologie du cerveau*, Amyot, Paris 1869, pp. 231-233.

[10] F.J. BROUSSAIS, *Cours de phrénologie*, J.B. Baillière, Paris 1835, p. 493.

[11] A. HALLER, *Elementa Physiologiae Corporis Hu-*

mani, François Grasset, Lausanne 1757-1766, VIII voll.

[12] F. MAGENDIE, *Précis élémentaire de physiologie*, tome I, Méquignon-Marvis père et fils, Paris 1836-1838.

[13] P. FLOURENS, *Éloge historique de François Magendie: suivi d'une discussion sur les fonctions distinctes des racines des nerfs*, Garnier Frères, Paris 1858.

[14] F. DUBOIS D'AMIENS, *Examen des Doctrines de Cabanis, Gall et Broussais*, H. Cousin, Paris 1842, pp. 364.

[15] F. LELUT, *Rejet de l'organologie phrénologique de Gall et des ses successeurs*, Fortin Masson, Paris 1843, pp. 405

[16] H. HELMHOLTZ, *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*, Vieweg, Braunschweig 1863.

[17] J.B. BOUILLAUD, *Discussion sur la faculté du langage articulé. Réplique au discours de M. le professeur Trousseau; nouveaux faits à l'appui de notre doctrine*, in: «Bulletin de l'Académie Impériale de médecine», n. 30, 1865, pp. 724–781. Interestingly, in the same volume, Armand Trousseau uses music as a beautiful, heuristic metaphor to explain the differences between aphasia and the paralysis of phonatory system: «gentlemen, let me use an analogy. Here we have a musician sit in face of a splendid piano: the keys make admirably move the strings, and these can resonate in a wonderful way into the harmonic sounding board; however, the musician cannot produce any sound from this excellent piano: and in fact, his hands are paralyzed. This man, he is the aphasic. Otherwise, next we have another musician filled with inspiration, with hands able to express the harmony that guide them, and anyway no sound hits our ears; the piano is broken. This man has no more an instrument: this is the subject impaired by labio-glosso-laringeal paralysis» (*ivi*, p. 656).

[18] J. FALRET, *Aphasie, Aphémie et Alalie*, in: A. DECHAMBRE (ed.) *Dictionnaire Encyclopédique des Sciences Médicales. Première série.* Simon Daçon, Paris 1864-1868, pp. 796.

[19] J. HUGHLINGS JACKSON, *Clinical Remarks on Emotional and Intellectual Language in Some Cases of Disease of the Nervous System,* in: «Lancet», vol. LXXXVII, n. 1, 1866, pp. 174-176.

[20] J. HUGHLINGS JACKSON, *Singing by Speechless (Aphasic) Children*, in: «Lancet», vol. XCVIII, n. 2508, 1871, pp. 430-431.

[21] F. COURMONT, *Le cervelet et ses fonctions*, Félix Alcan, Paris 1891.

[22] M. LEVEN, F. OLLIVER, *Recherches sur la physiologie et la pathologie du cervelet*, pp. 80, in : E. FOLLIN, C. LASÈGUE (ed.) *Archives Générales de Médecine*, P. Asselin, Paris 1863, 6, 1, pp. 765.

[23] C. WERNICKE, *Der aphasische Symptomencomplex*, Cohn and Weigert, Breslau 1874.

[24] A. KNOBLAUCH, *Ueber Störungen der musikalischen Leistungfähugkeit infolge von Gehirnläsionen*, in: «Deutsches Archiv für Klinische Medicin», n. 43, 1888, pp. 331-352.

[25] P. BLOCQ, *L'Amusie*, in: «Gazette Hebdomadaire de Médecine et de Chirurgie», n. 8, 1893, pp. 86-90

[26] S. PINKER, *How the Mind Works*, W. W. Norton & Company, New York 1997.

[27] N.L. Wallin, B. Merker, S. Brown (eds.), *The Origins of Music*, MIT Press, Cambridge 1999.

[28] I. PERETZ, M. COLTHEART, *Modularity of Music Processing*, in: «Nature», vol. VI, n. 7, 2003, pp. 688-691.

[29] A. PATEL, *Music, Language and the Brain*, Oxford University Press, New York 2008.